DEVELOPING THE ANTHRACITE RESOURCE: ELECTRICITY GENERATION OPTIONS

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SUMMARY

Vietnam has a broad range of energy resources available to develop including coal, oil, gas and water. While there is need for a balance of energy resources coal is one promising cheap electricity.

The coal resources of Vietnam are mainly anthracite occurring in geologically difficult situations for mining. This makes the coal relatively expensive to recover because of the highly faulted condition.

Anthracite has some excellent coal properties but has a low volatile matter content making it more difficult to burn effectively. A range of equipment exists to utilize anthracite efficiently. Effective combustion depends upon longer residence time in the hot zone of the furnace. This may be achieved by a combination of reducing coal feed particle size and using downshot firing or allowing a larger coal particle size combined with a circulating bed configuration.

The latter is preferable if the sulfur content of the coal is high as this can be reduced more economically by the addition of limestone to the bed.

Early anthracite boilers needed oil support to keep the flame from extinguishing. However modifications to the original pulverized coal design allowed satisfactory combustion in downshot type furnaces using coal pulverized finer than industry standard for black coal.

More recently circulating fluidised bed boilers have also proved effective. Both technologies depend on increasing the residence time in the hot zone in the furnace to achieve a fairly good burnout and little residual carbon in ash.

Recent work on the gasification of petcoke, a by-product of oil refining, has been very successful in a number of demonstration gasifiers. The properties of anthracite are similar to petcoke, making gasification a real alternative. This opens the way for tri- and polygeneration of higher value products and electricity as a by-product.

Any of theses technologies can be used for Vietnamese coals, the choice will depend upon experience with similar fuels and contract details offered by manufacturers of equipment using these technologies. In the long-term gasification producing a range of higher value products would offer the prospect of a more profitable operation not so closely linked to a fixed price product, electricity.

1 INTRODUCTION

Electricity of Vietnam operates the high voltage power system in Vietnam. The present capacity of this power system is about 4700 MW. This would suggest that new units could have a capacity up to about 500 MW for system security reasons. The per capita electricity consumption is about 250 kWh per year showing the capacity for increasing usage.

Of the 4700 MW about 645 MW is coal fired (~14%), 198 MW is oil fired (~4%), 688 MW is gas turbines (~15%), 360 MW is diesel generation (~8%) and 2810 MW is water power (~60%).

The majority of the coal-fired units are in the Northern region with 440 MW at Pha Lai, 110 MW at Ninh Bin and 105 MW at Uong Bi. All these units are of Russian or Chinese origin. Some are operating at less than nameplate capacity.

In 1998 a start was made on extensions to Pha Lai Power Station located about 45 km north east of Hanoi. Two 300 MW units are being installed at a cost of USD545m. The boilers are being supplied by Mitsui Babcock using experience on anthracite gained in China and Vietnam. The new units are expected to run in January and June 2002.

There are plans for a number of new plants. The main proposals are for 720 MW at Phu My 3, 300 MW at Quang Ninh, 720 MW at Phu My 2, 50 MW at Ormat, 72 MW at Can Don and 475 MW at Soc Trang.

In addition to those power stations proposed by EVN the Vietnam Coal Corporation (Vinacoal) has announced plans for a total of 2170 MW of plant to be built using lower grade coal from Na Duong. This coal is typically 3500 kcal/kg and up to 6.5% sulfur. The first 100 MW unit will be started in late 2000 to run in 2003. It is suggested that the units will be designed by Vinacoal and be of the CFB type to facilitate sulfur removal.

Present retail power prices in Vietnam are about USD 0.058/kWh which appears to be less than real production costs.

2 ANTHRACITE RESOURCES

Vietnam has fossil energy resources of coal, oil and gas. The coal resources are predominantly anthracite and are located in the north of the economy at Quang Ninh. Estimates of reserves are about 3.5b tonnes. This coal is not easy to recover because of complicated geology.

There is a broad range of quality. Moisture is relatively low at 6-8%. The ash content is highly variable and may lie between 5 and 40% although coal with a fairly consistent ash is available. Volatile matter is low and ranges from 5-8%. Sulfur content is generally low at less than 1% but there are some areas with much higher values.

The specific energy can range from 4500 to 8300 Kcal/kg and Hardgrove Grindability Indicies ranges from 30 to 60.

Some anthracite is exported to Japan and elsewhere. Export coal range of properties moisture 4-8%, ash 3-40% dry, volatile matter 5-8% dry, sulfur ~0.6%, specific energy dry kcal/kg 5500-8100, fixed carbon 62-86% dry, HGI 29-62.

3 ELECTRICITY GENERATION FROM ANTHRACITE

The development of pulverized coal combustion in the 1930s allowed the development of coal as a cheap efficient source of energy for power generation. While bituminous coal was used first, research and industry development has broadened the range of coals and their properties that can be used to generate power effectively and economically.

This has extended to anthracite, a low volatile coal with high carbon content. For effective combustion the reduced reactivity of anthracite requires one of two specific technologies to ensure efficient burnout and minimum carbon loss.

The first of these technologies uses finer coal particles and increased residence time in the furnace. For bituminous coal the normal fineness for effective combustion is about 70% of particles less than 75 microns. Anthracite requires significantly finer coal with up to 95% less than 75 microns in some cases. This requires reducing the capacity of the pulverizing plant and using special classifiers on the pulverisers to recirculate coarser particles until the necessary fineness is achieved.

The necessary additional residence time for the finer particles can be achieved by downs hot or arch firing where the pulverized coal / air mixture is directed in a downward direction followed by an upward flow to increase residence time without increasing furnace volume excessively.

The second technology achieves similar results by using rather larger particles of coal in a circulating fluid bed (CFB) of hot particles of ash and partly reacted coal particles. Here the particles are recirculated within a hot zone until the majority of particles are burnt out leaving little residual carbon to reduce unit efficiency.

More recently tests in demonstration gasifiers in a number of economies have resulted in effective utilization of petcoke, a by-product of the oil refinery industry. Anthracite has similar properties to petcoke so gasification is now a real possibility.

4 AVAILABLE ANTHRACITE COMBUSTION TECHNOLOGY

There are a number of equipment suppliers of both approaches to burning anthracite effectively. Some examples of the effective use of this technology in Vietnam and elsewhere are set out below.

4.1 Conventional pulverized coal boiler plant

There are a number of equipment suppliers for modified conventional pulverized coal boilers suitable for utilizing anthracite. A number of examples follow, the first being the new units at Pha Lai Power Station near Hanoi.

4.1.1 Mitsui Babcock

The earlier units at Pha Lai had wall-fired Russian boilers with a capacity of 55MW, two to a 110 MW turbine. There are four such units operating at reduced capacity. The two new units have a capacity of 300 MW each. The boilers are provided by Mitsui Babcock and are down shot fired. Final steam conditions are 540C/540C and 174.6 kg/cm2. These are presently the largest down shot fired boilers in the world.

The design is based upon units at Yue Yang power station in China. These are 362 MW capacity and burn a similar quality anthracite. They were commissioned in 1991.

The Pha Lai boilers slot burners are located on each of the firing arches. Fine coal from ball mills, about 95% less than 75 microns, is fed to these burners together with primary air at high temperature. Extra air is fed from the arch to force the flame front downwards. Part of the lower furnace is refractory lined to assist in keeping high furnace temperatures. The boiler is natural circulation with ribbed tubing in selected regions to cope with the high local heat flux. These components ensure ignition and long residence times for the fine coal.

The anthracite has about 9% moisture, 30% ash, 5% volatiles, Hardgrove Grindability Index of 66 and specific energy of 5080 Kcal/kg.

In addition Mitsui Babcock have units at Yue Yang (2x350 MW, 1987), Heze (2x300 MW 1998), and Liaocheng (2x600 MW 1998) in China using similar technology burning anthracite.

4.1.2 Foster Wheeler

There are other suppliers of downshot-fired boilers for low volatile coals such as anthracite. Foster Wheeler has installed many such boilers in Europe and more recently in China. There are four units in China at Yangcheng, Ezhou, Yangquan and Shangan. New units are being built for Hanfeng will be 715MW capacity each, firing a blend of anthracite and bituminous coals.

It uses the arch firing principle to increase residence time in the furnace. Capacities range from 250 to 500 MW. They have utilized coal with volatiles as low as 5.5% effectively

4.2 Atmospheric fluidised bed boiler plant

World Bank documents list 13 suppliers of atmospheric fluidised bed boilers. A group of these have extended their plant design knowledge to cover the effective combustion of low volatile coals. Units may be bubbling bed or circulating bed with circulating bed units generally being used for anthracite combustion.

These boilers are capable of removing a high proportion of released sulfur oxides using limestone injected into the bed. This provides a capital cost advantage over conventional units with flue gas desulfurization where very high efficiency sulfur removal is not required.

CFB technology has some advantages over more conventional technology in simplicity, reduction of sulfur oxides, good turn down ratio as well as stable operation with low reactivity fuels.

4.2.1 Foster Wheeler circulating fluidised bed unit

Foster Wheeler has a 110 MW boiler at the Gaoba Power Station of the Sichiuan Electric Power Administration at Neijaing. This unit was placed in service in 1996. It produces 114 kg/s of steam at 540C and 98 bar. It has two refractory lined cyclones 7.5m. in diameter. Circulating gas velocity is about 5m/s.with 20% excess air. The boiler efficiency is about 90% with availability above 90%.

It uses local Sichuan coal with high sulfur and ash combined with low volatiles. Typical values are total moisture 6-12%, ash 27-37%, volatile matter 7-9% with a LHV of 19.3 Mj/kg. Coal is crushed to less than 7 mm before entering the boiler.

Minimum stable load is 30% without oil support. Auxiliary power is about 3.5%. Under test conditions SOX was 680 mg/m3 and NOX 64 mg/m3. Foster Wheeler has other 50 MW units using this technology running and are looking to a 300 MW demonstration unit

4.2.2 ABB Combustion Engineering circulating fluidised bed unit

ABB Combustion Engineering has installed 2x220 MW units at Tonghae in Korea. These circulating fluidised bed units commenced operation in 1998 and burn local anthracite.

Typical coal property values are ash 40-45% and sulfur 0.5-1.5%

4.2.3 Babcock & Wilcox circulating fluidised bed unit

Babcock & Wilcox have developed an internal recirculation fluidised bed boiler design (IR-CFB unit) that can be installed directly or retrofitted in an older existing pulverised coal boiler. About 17 of these units have been installed using a broad range of coals. More recently two units of 140 and 163 MW are being installed in Russia to utilise high

ash anthracite. Some earlier units have operated on petcoke, which has low volatiles like anthracite.

4.3 Pressurized fluidised bed boiler plant

It is possible to operate a fluidised bed above atmospheric pressure. This allows an increase in efficiency of the overall process and smaller plant for the same capacity. The process was developed in the UK and ABB took over the commercialisation. Plants using this technology have been built at Vartan in Sweden, Wakamatsu in Japan, Tidd in the USA, Escatron in Spain and Karita in Japan. Unit capacities are about 80 MW (P200 module) and 350 MW (P800 module).

ABB Carbon, now Alstom Power has carried out tests using anthracite in its process test facility (PTF) in Sweden. A broad range of coals has been tested to determine the performance envelope within which the process can operate effectively. The PTF has a capacity of about 1 MW thermal.

Anthracite from Vietnam has been tested in this facility as part of the program. The properties of the test coal were ash 7.0 % dry, Volatiles 5.4% daf, Sulfur 0.31% as fired and specific energy LHV 32.5 Mj/kg as fired. While this was at one end of the range of coals it performed successfully and could be used as a fuel for a PFBC plant.

The PTF also carried out tests using added wood chips to the test coal to determine the cofiring capability of this technology.

4.4 Gasification

At a recent conference in San Francisco on Gasification of many fossil resources work on gasifying petcoke was reported. Petcoke is a by-product of oil refining. However the properties of petcoke are similar to anthracite in that they are high in carbon and low in volatile matter. The results obtained for petcoke could be applied to anthracite very effectively.

This would open up the known potential of gasification to produce a series of product streams as well as electricity. These streams of heat, hydrogen and chemicals are of significantly higher value that electricity and would result in a much more profitable operation.

4.5 Cofiring with biomass

While little has been reported there is a case to consider cofiring anthracite with biomass. The biomass could be used to provide a source of hot gases to help provide adequate local ignition temperature and energy input. It would also add to the combined volatile matter available. Vietnam has ample biomass available and this may be a possibility in future installations.

5 ISSUES

There are a number of local issues of concern for any proposed generation installation in Vietnam.

5.1 Generation

EVN is a state monopoly at a time when many economies are moving towards a competitive electricity market situation. Contracts entered into under monopoly conditions may not be appropriate when changes are made to a competitive market.

The price of coal is relatively high. Productivity improvements need to be made to reduce the cost of coal for power.

5.2 Financial

For international contractors there is difficulty in either obtaining contracts in convertible currency or in stable conversion of the local currency.

Local organizations are given preference in some matters.

5.3 Environmental

While there are some environmental limitations with coal it remains an effective component of the energy mix for Vietnam.

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Developing anthracite resources, electricity generation options

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Vietnam energy mix

- Coal, 645 MW 14%
- Oil, 198 MW 4%
- Gas, 688 MW 15%
- Diesel, 360 MW 8%
- Water, 2810 MW 60%

Anthracite resources

- Reserves about 3.5b tonnes
- Located mainly in the north
- Difficult geology for recovery
- Relatively expensive mining
- Variable coal properties

Anthracite properties

• Moisture content	6-8%
• Ash content	5-40%
• Volatile matter	5-8%
• Sulfur	0.5-5%
• Specific energy	4500-8300 kcal/kg
• Hardgrove Index	30-60

Power generation options

- Modified conventional pulverised coal
- Atmospheric fluid bed
- Pressurised fluid bed
- Gasification

- Low reactivity needs longer residence time for burnout

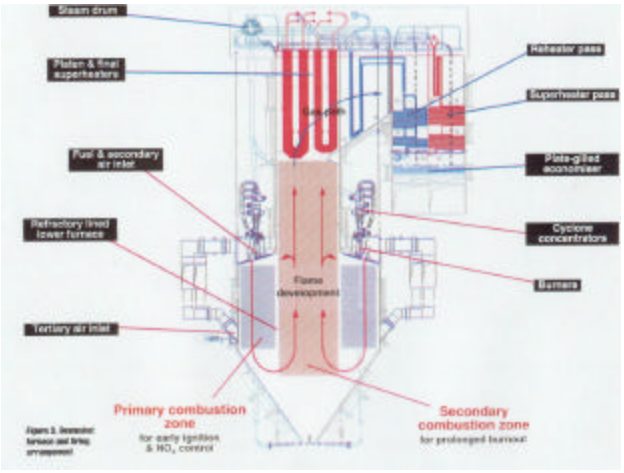
Modified conventional generation

- Finer particles, up to 95% less than 75 microns
- Downshot firing to increase residence time
- Otherwise fairly conventional

Modified conventional suppliers

- Mitsui Babcock
- Foster Wheeler

Pha Lai Power Station boiler



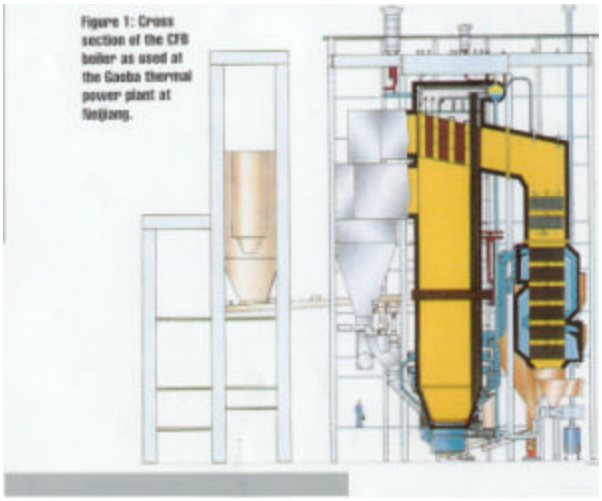
Atmospheric fluid bed

- Coarser particles 5-12mm diameter
- Circulating bed to increase residence time for anthracite
- Recirculation ratio 2-5

Atmospheric FB suppliers

- Foster Wheeler
- ABB Combustion Engineering
- Babcock and Wilcox

Gaoba Power Station, boiler



IR-CFB boiler

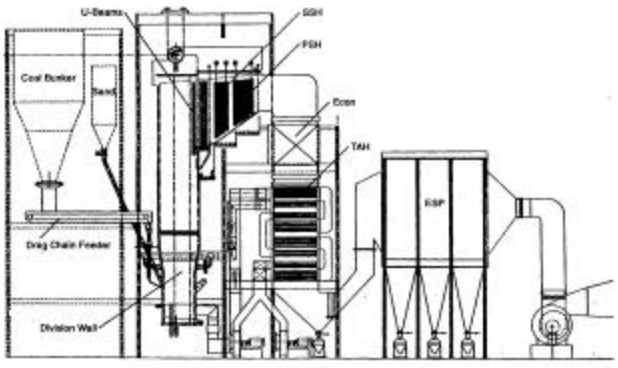


Figure 3 KCIL IR-CFB boiler – general arrangement.

Pressurised fluid bed

- ABB / Alstom and licensees
- Higher efficiency
- Vietnamese anthracite satisfactory tests
- Existing installations use black coal

PFBC suppliers

- ABB/Alstom basic technology
- Various licensees
- IHI, Karita 350 MW
- Hitachi, Osaki 250 MW

Alstom P200 PFBC system

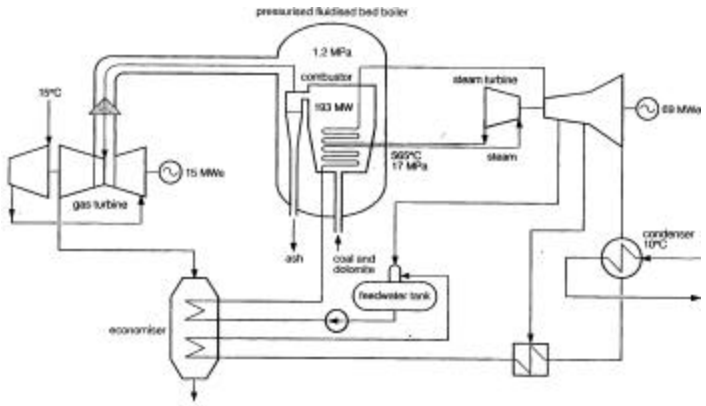


Figure 8 **ABB P200 PFBC system** (Pillai and others, 1989)

Gasification, IGCC

- Numerous suitable gasifiers
- Use of petcoke in US demonstration plants
- Similar properties to anthracite
- Co-, tri- and polygeneration potential
- Power, heat, fertilizers, chemicals

Gasifier suppliers

- Texaco, Polk PS technology
- E Gas, Destec, Wabash PS technology

Polk Power Station, Texaco IGCC system

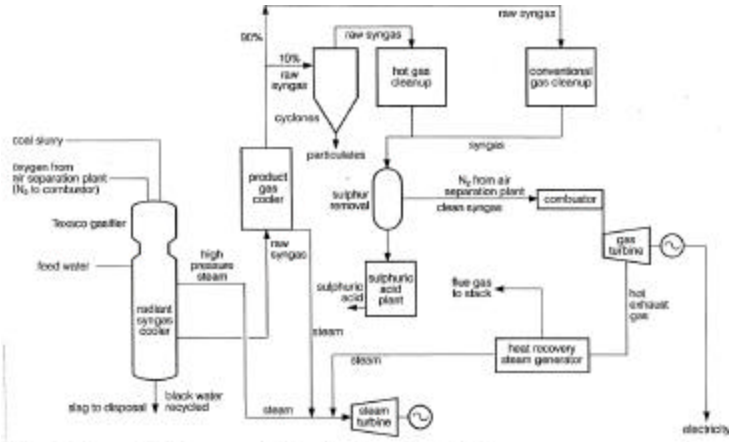


Figure 10 Texaco full heat recovery IGCC system (Tampa Electric, 1996)

Cofiring with biomass

- Possible technology to provide hot gases to assist combustion of anthracite
- Vietnamese biomass availability

Development issues

- GENERATION
- monopoly move to competitive
- high coal price
- FINANCIAL
- currency conversion
- local preference
- ENVIRONMENTAL